Southern African Large Telescope High-Resolution Spectrograph

SALT HRS

3220AE0004 Mechanical Design – Overview

Graeme Kershaw
P.L. Cottrell
University of Canterbury

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Issue History

Number and file name	Person	Issue	Date	Status
3220AE0004 mechanical	GMK	1.1	1-Mar-05	First draft
	PLC	2.0	6 March 05	CDR update
		2.1		?
	GMK	2.2	10 March 05	Insert echelle info, extra figs
	PLC	2.3	13 March 05	Tidy up

TABLE OF CONTENTS

1 Scope

This document describes the mechanical design rationale and summarizes the key elements of the SALT HRS instrument.

This replaces the PDR document with the same number except that it is Issue 2.

2 Requirements

2.1 Interface

SALT HRS will interface to the optical fibres from the telescope and the CCD detectors, as well as to power and LAN associated with the SALT facility.

2.2 Design Goals

The mechanical design of this spectrograph is required to meet clearly defined criteria:

1. To provide a stable and precise mounting platform for the optical components;
2. To provide initial and future accessibility for all necessary adjustment and alignment procedures;
3. To provide a self-contained package to allow for ease of assembly and maintenance;
4. To provide a solution to problems faced in transporting and installing this instrument in a 'remote' location;
5. To provide a safe and convenient method of maintaining and servicing this instrument;
6. To provide the necessary interface regions for the fibre feed input and the CCD detector.

Notes on figures in this document
All the figures in this document are generated by the following software:

Mechanical Desktop Version 6 by AutoDesk
Mechanical Inventor Version 6 by AutoDesk

These figures are JPEG images generated directly from a full 3D solid model of the spectrograph design. The 3D model is a dimensionally and materially exact representation and is **not** in any way an 'artists impression'.

2D working drawings of the components are generated directly from this solid model. Extensive sets of these are included in the additional document (3220AD0005 mech spec).

The Finite Element Analysis (FEA) images are generated by **Mechanical Desktop Version 6**. In some cases the elements may have been redrawn to simplify the task of the FEA facility.

3 Major Mechanical Components

This instrument will be a relatively large static structure, approximately 3.3m long and 1.1m in diameter and weighing about 2000kg (see Figure 1). The instrument consists of an optical bench in the form of a weldment with one extension to accommodate the collimator mirror (Figure 2).

The optical bench (see for example Figure 3) precisely locates the major optical components and has a truss extension at one end to support the collimator mirror. The échelle grating, the camera lens assemblies and their respective VPH gratings, the dichroic and the input and output fold mirrors are all contained on the optical bench. Each of these components will be described in more detail in the following sub-sections.

The optical bench is a fully floating structure and is attached only to the tank at the camera and input optics lid where the cameras and the input optics are located (see Figure 1). The optical bench also rests on two rails inside the tank via a pair of rollers that serve to decouple the bench from the tank and to isolate it from the effects of changes in barometric pressure. The tank is isolated from the floor with anti-vibration mounts.

The user operated moving parts are the input fold mirror for direct fibre input or for image slicer operation, the slit-viewing mechanism (see 3230AE0030), the focus mechanism using small movements of the pupil mirrors and the fast and slow shutters. These will described in Section 3.8.

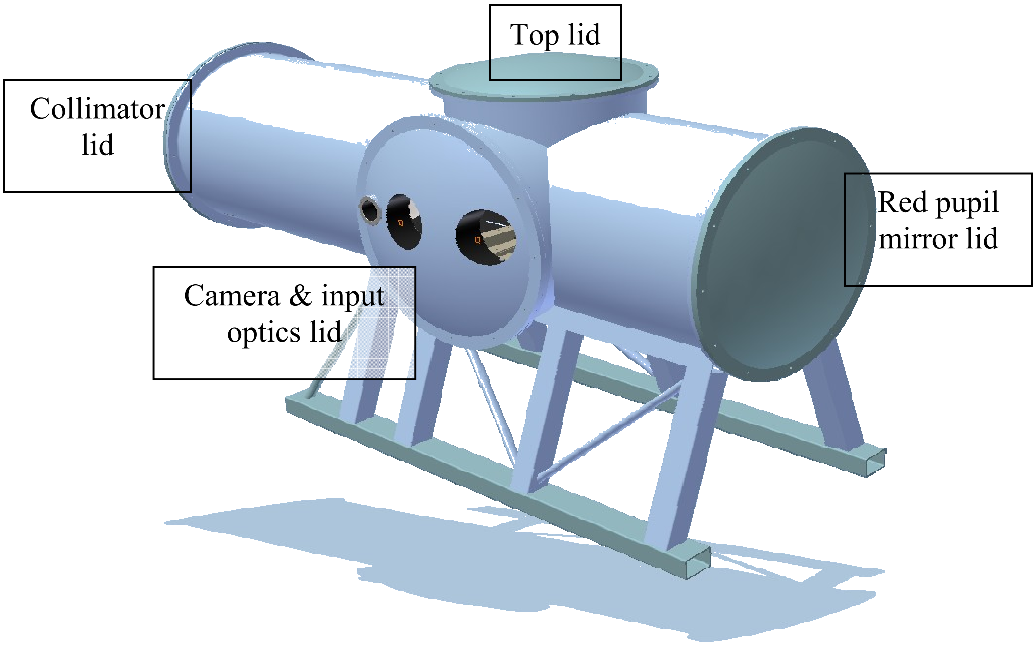

Figure 1: Tank structure for the whole spectrograph. The 'lids' provide primary access to the components noted. The 'Top lid' will provide access to the central part of the optical bench.

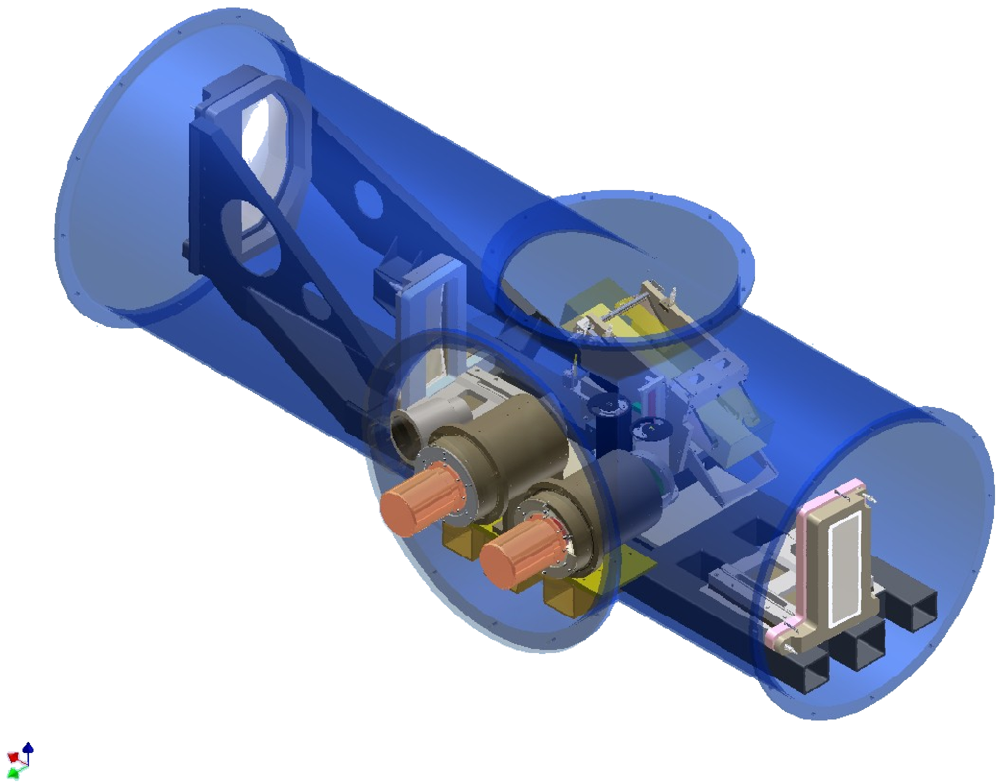

Figure 2: The spectrograph's internal components. These will each be described in Section 3.

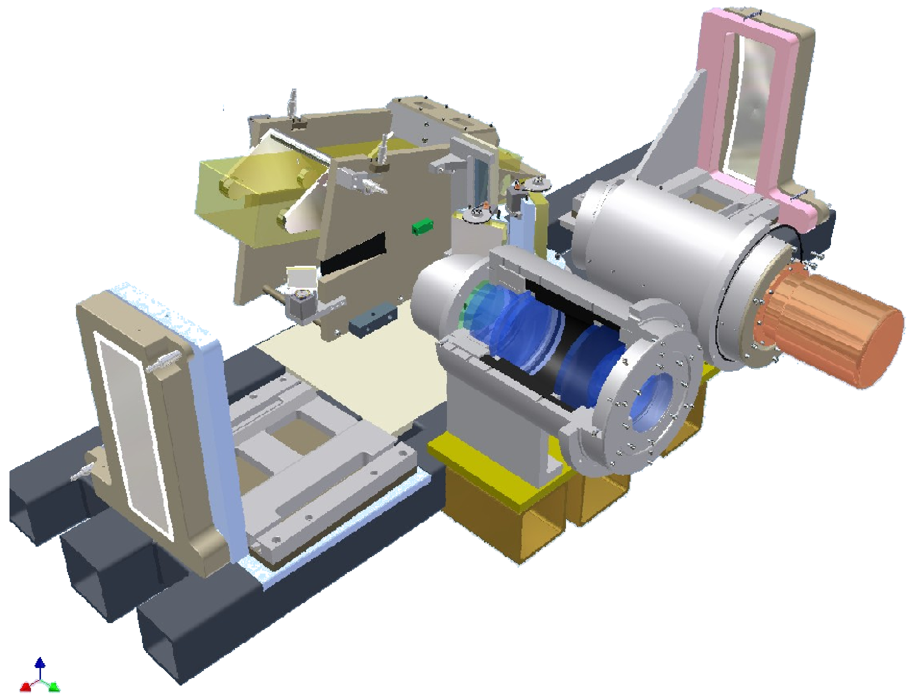

Figure 3: The spectrograph components on the central optical bench viewed from the blue pupil mirror end. (The collimator, with its truss extension is not shown.)

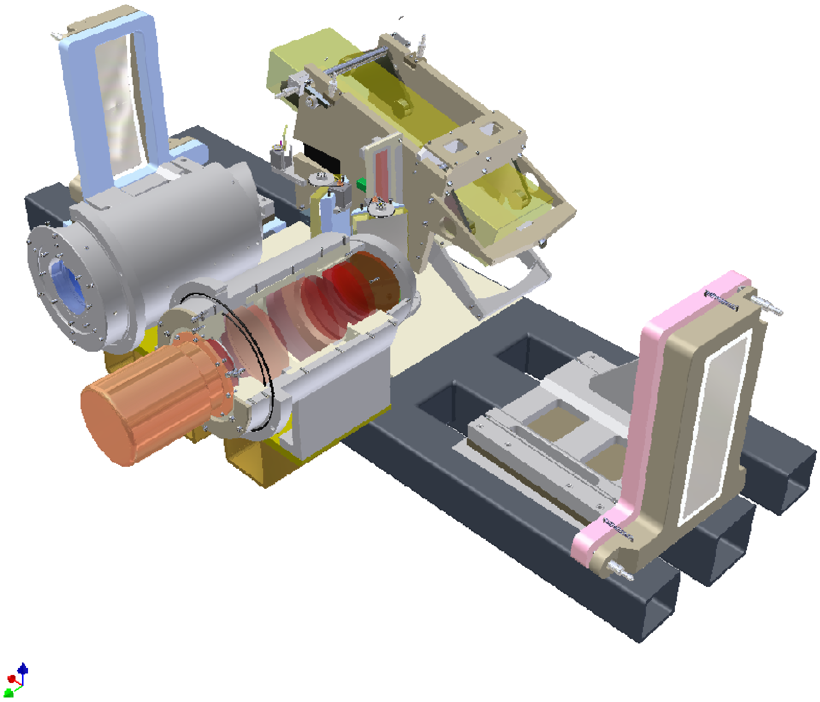

Figure 4: The spectrograph components (viewed from the red pupil mirror end).

3.1 The optical bench and its associated components

The central base of this instrument is a custom-made weldment designed to accommodate all the major components except the collimator mirror and its cell (Figures 3 and 4). The major optical components are directly attached to this, their mountings being bolted to a prescribed hole pattern.

The components that are attached in this way are the red and blue cameras and their respective VPH grating, the red and blue fold mirrors and their slow shutters, the échelle grating and its base. The dichroic and its associated mounting and the diagonal mirror in the input beam and the direct fibre injection module are mounted onto the échelle assembly.

Figure 5 shows that the camera assemblies will be mounted on a series of cross members that will be bolted to the main weldment, enabling a sequential assembly procedure.

3.2 Input arrangements

The input optics inside the tank is shown in Figure 6. The ‘slit pocket’ is an enclosure in the side of the tank that houses the external input optics, including the image slicers and an external fast shutter, slit viewing optics and ancillary transfer optics. These are described and detailed in 3230AE0030 and its companion specification drawings 3230AD0032. A slit plate and a telecentric lens (**TBD1**) will be mounted off this slit pocket and also attached to the optical bench weldment to ensure mechanical stability.

Light from the FIF of SALT is either input through the ‘slit pocket’ and be reflected off the input fold (also described as a flip mirror in the specifications 3220AD0005) mirror (for the medium and high resolving powers) or injected directly into the spectrograph (direct fibre input for the lowest resolving power mode). The details of the mounting of the direct fibre and fast shutter are still being developed (**TBD2**). Control of the input fold mirror is described in 3250AE0029.

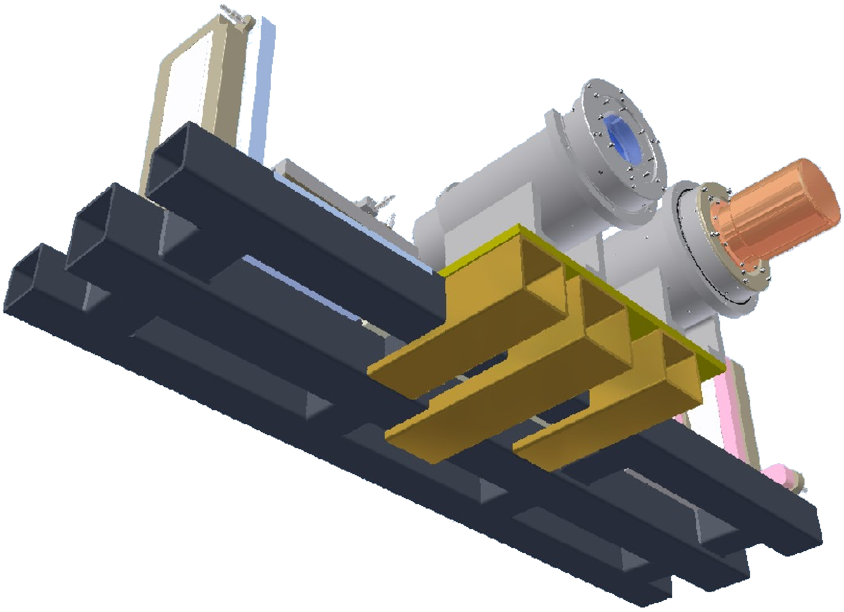

Figure 5: Blue camera pupil mirror and underside of weldment showing optical bench cross-members.

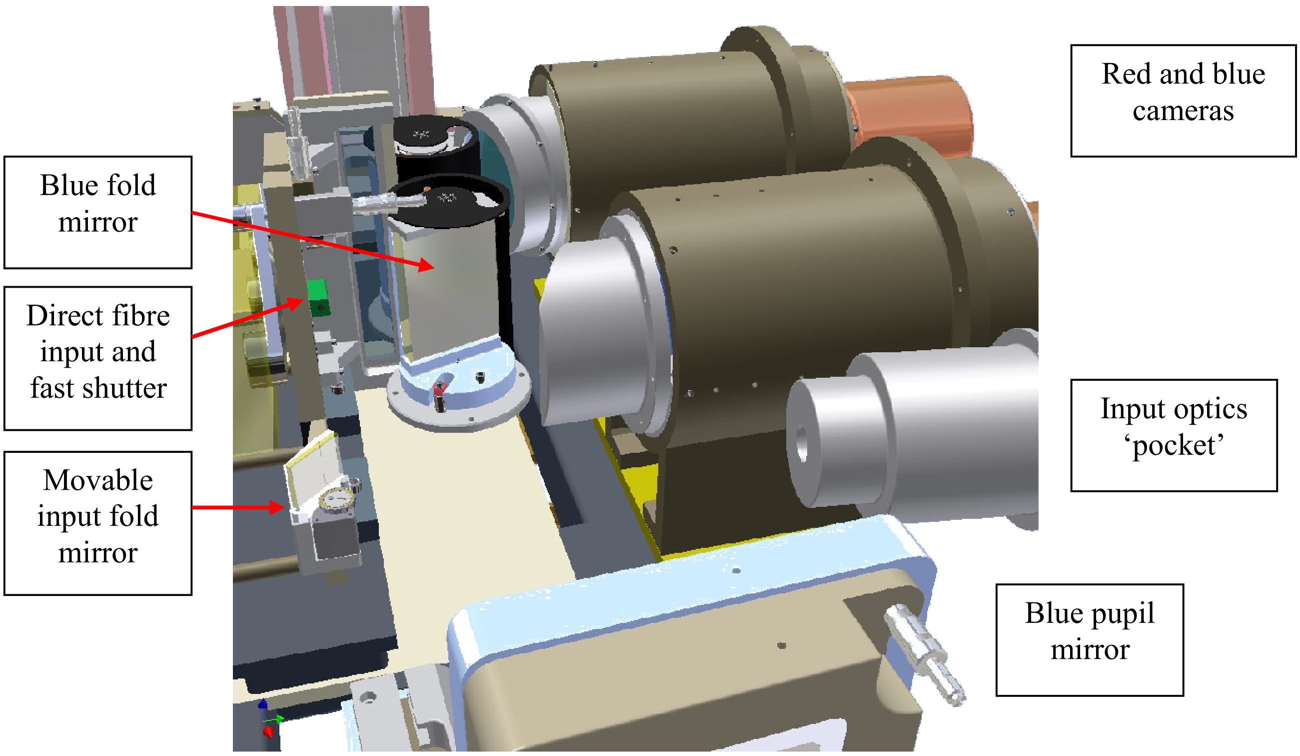

Figure 6: Input optics ‘pocket’ (centre right), movable input fold mirror (left), direct fibre input (centre left), blue pupil mirror (foreground) and blue fold mirror with red and blue cameras (middle and top right).

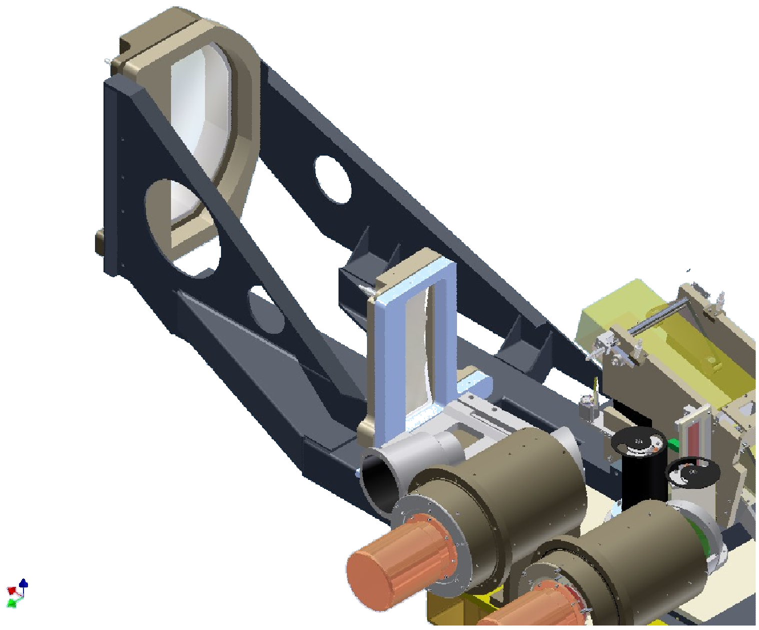

Figure 7: Collimator mirror and support structure.

3.3 The collimator mirror truss and cell

To avoid a heavy extension to the optical bench weldment, a light weight truss assembly has been employed to support the collimator mirror in its cell (see Figure 7). Attachment points on the weldment have been suitably positioned to allow this without interfering with the optical path.

The collimator mirror cell is made from an aluminium casting roughly rectangular in shape but rounded on one side to accommodate the shape of the glass substrate. Its internal dimensions are the same as the external dimensions of the mirror plus 15mm (**TBC1**). The space thus created is filled with an elastomer which will provide full support for the mirror without distortion. A large variety of elastomeric compounds are available for this purpose. We propose to use Silgard 184 and 186.

This cell is fitted with 2 micrometers and a pre-loaded ball joint to allow alignment of the mirror in its cell and a counter cell. The micrometers provide X &Y adjustment. The 'counter cell' has the mounting points for the trusses which attach the mirror assembly to the main optical bench. This arrangement is typical for the pupil mirror, the dichroic mount and the collimator mirror and is shown in Figure 8 (see also 3220AD0005-000A, A1 and B).

The trusses will be constructed from a weldment in the form of steel plates attached to the 'optical bench' weldment and stiffened to avoid undue flexibility (Figure 7). The collimator mirror assembly will simply bolt to the structure. Because the mirrors and cells are of modest size and weight the deflection of the trusses will be negligible and the centring tolerance is very low (± 1mm see table 3 of 3210AA0007).

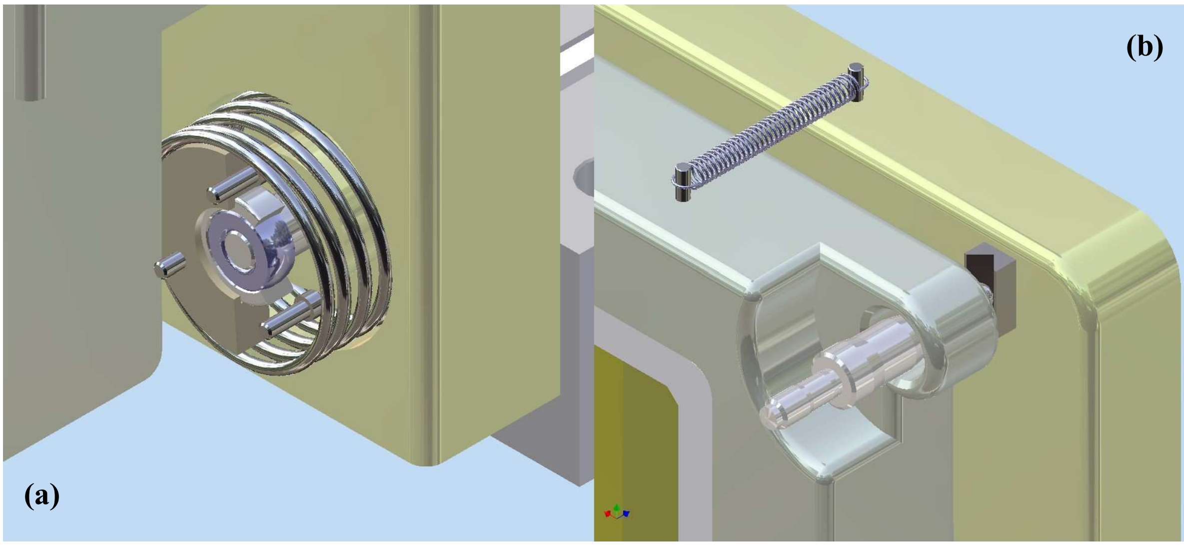

Figure 8: (a) Preloaded ball pivot as used in the collimator mirror, dichrioc mount and red and blue pupil mirror mounts. (b) Spring-loaded micrometer adjustment for tilt in these mounts.

3.4 Échelle grating and its alignment mechanisms

The grating will be supported securely in a 'face down' configuration (Figure 9) using inserts in 8 blind holes, 4 on each side of the grating substrate (Figure 10). The blind holes will be machined in the substrate by the grating manufacturer. The position of these 8 holes are arranged to coincide with the calculated 'Airey' points and they will be fully floating. The grating mount (Figure 11) will be fully adjustable to align with the other optical components.

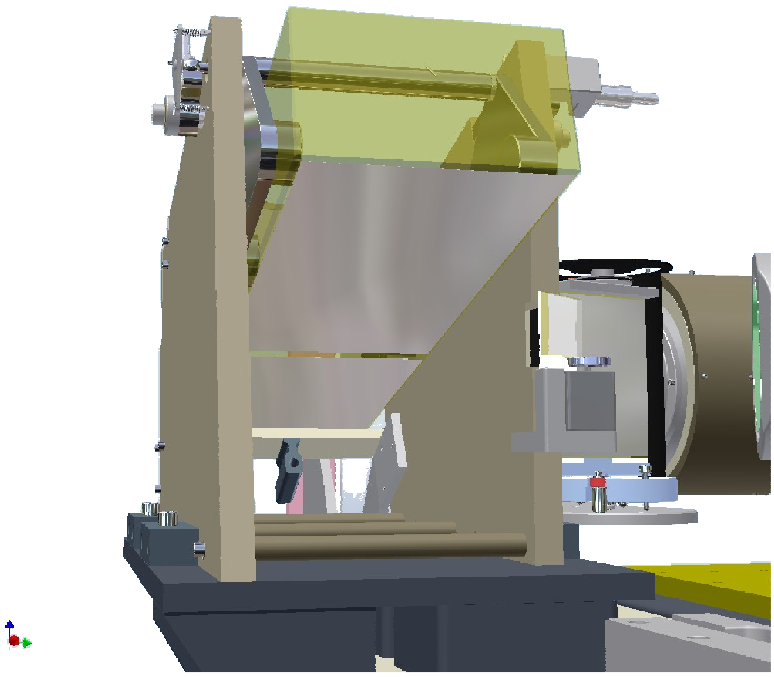

Figure 9: Échelle mounting sub assembly showing grating surface face down.

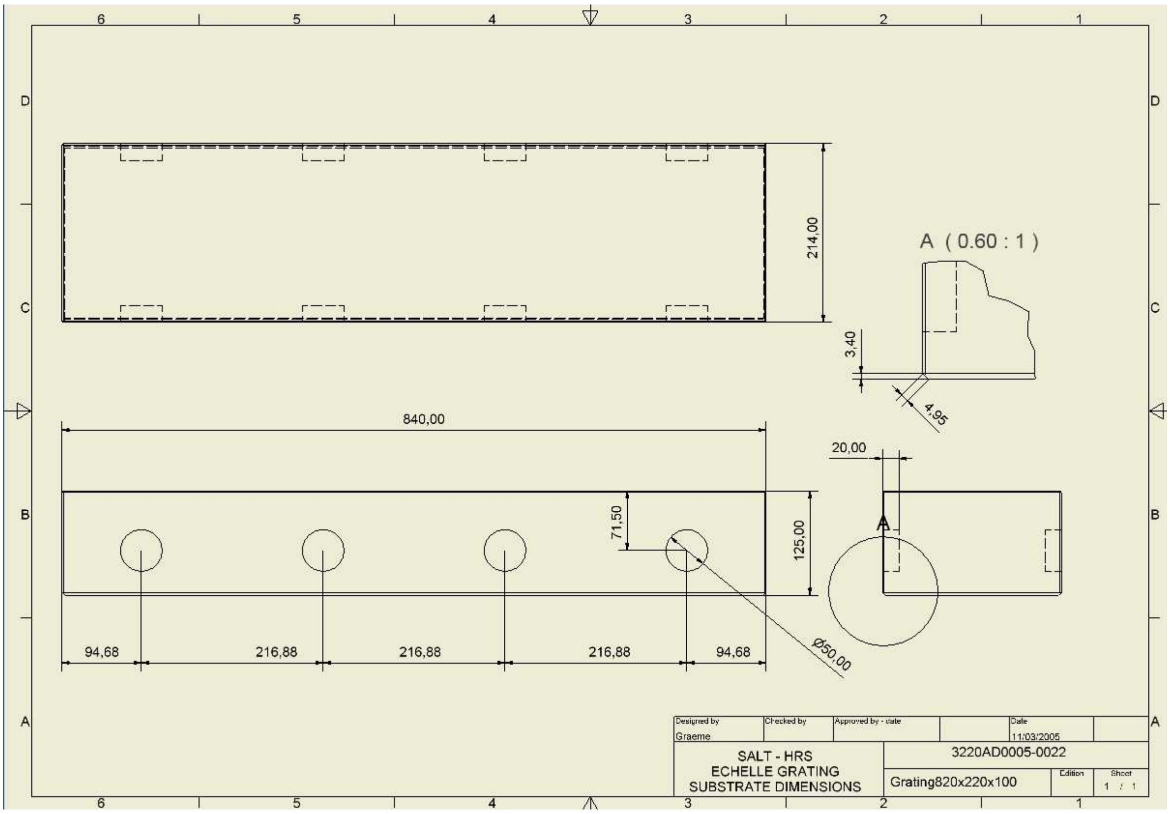

Figure 10: Grating substrate specifications showing machined holes (3220AD00005-0022).

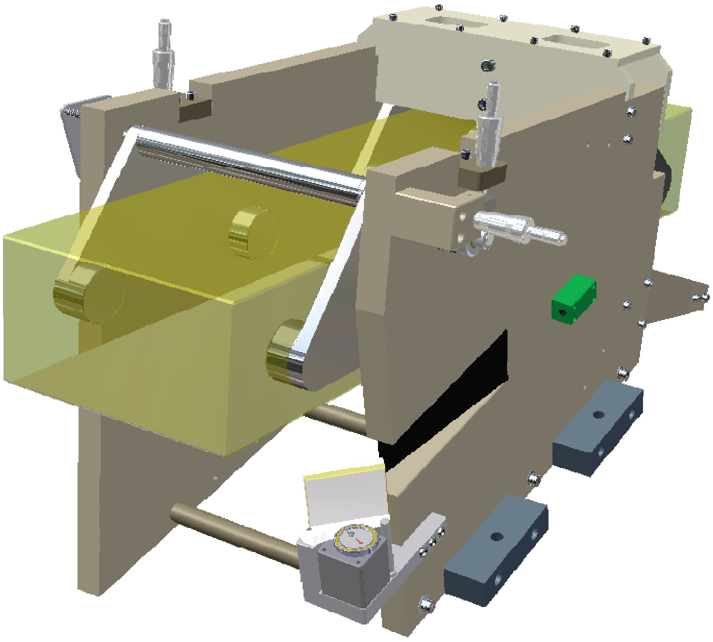

Figure 11: Grating support overview.

Three micrometers will control the grating position in pitch, yaw and roll. The micrometers will act upon a lever which will in turn raise or lower the supports at one end of the grating. The other end of the grating is held in position by a spherical bearing to allow for the necessary movement in 3 axes (see Figure 12).

A FEA (Finite Element Analysis) of the grating supported in the manner described above shows the type and magnitude of deflection that will be expected (Figure 13). A schematic diagram (Figure 14) shows the grating support assembly's constraints and degrees of freedom. The curved red arrows show rotational freedom while the straight red arrows (or groups) show directions of constraint. Three axes are shown about which the grating can be adjusted. This is done by rotating the micrometers (Figures 15 and 16) either individually or together to provide the appropriate movement. It can be seen that two of the axes are not independent of each other. Allowing this feature greatly reduces the complexity of the mechanism and improves stiffness in the mounting.

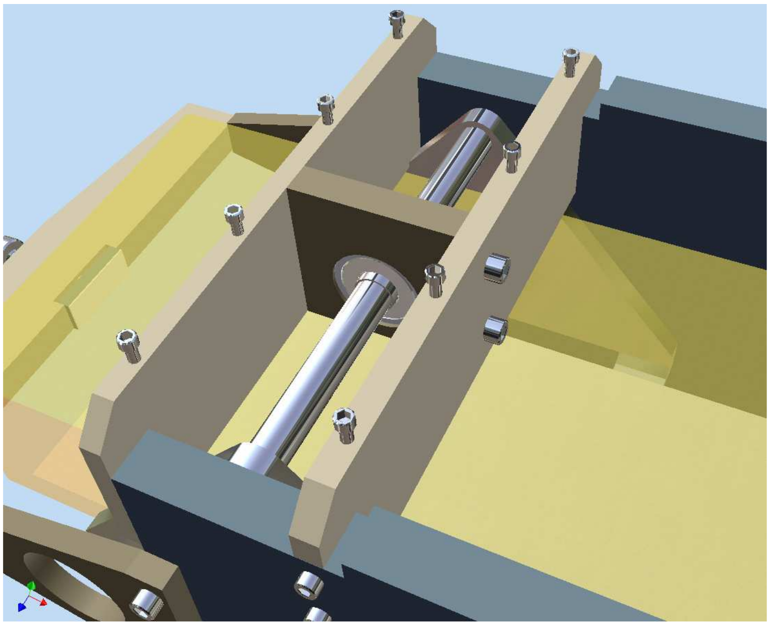

Figure 12: Spherical bearing assembly for échelle grating mount.

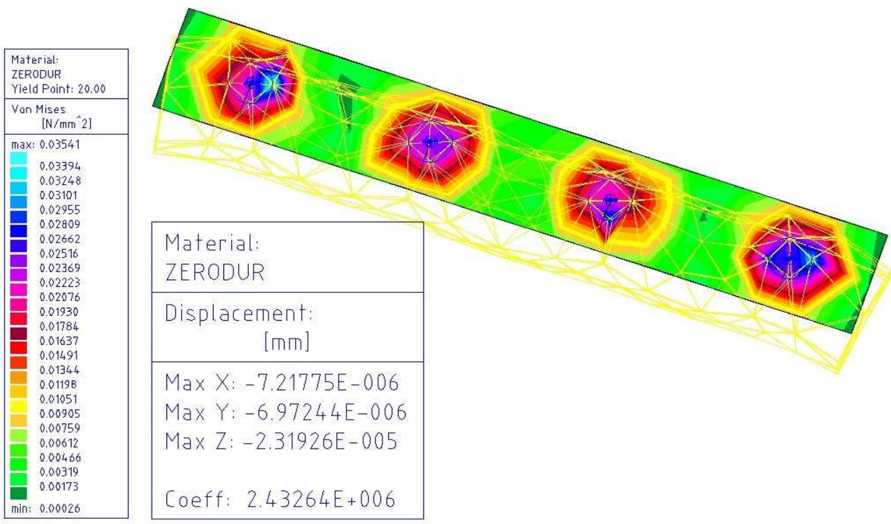

Figure 13: Grating FEA. The deflections are ~7nm in X and Y (gravity direction) and ~20nm in Z.

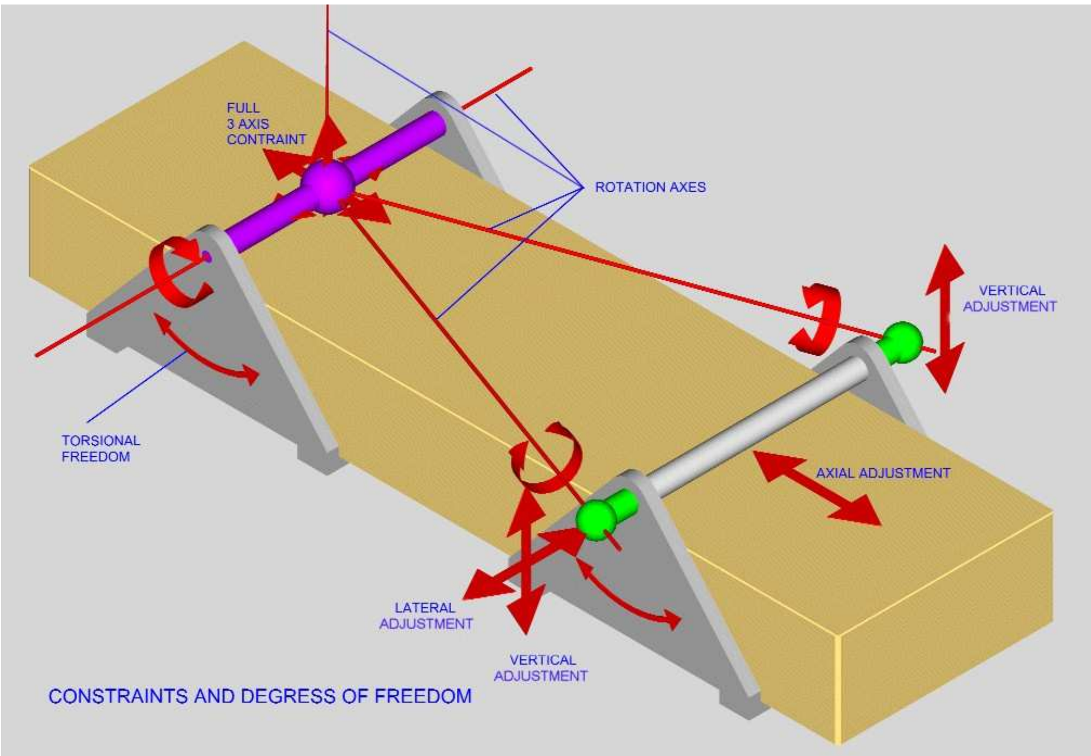

Figure 14: Constraints and freedoms in the échelle grating mount.

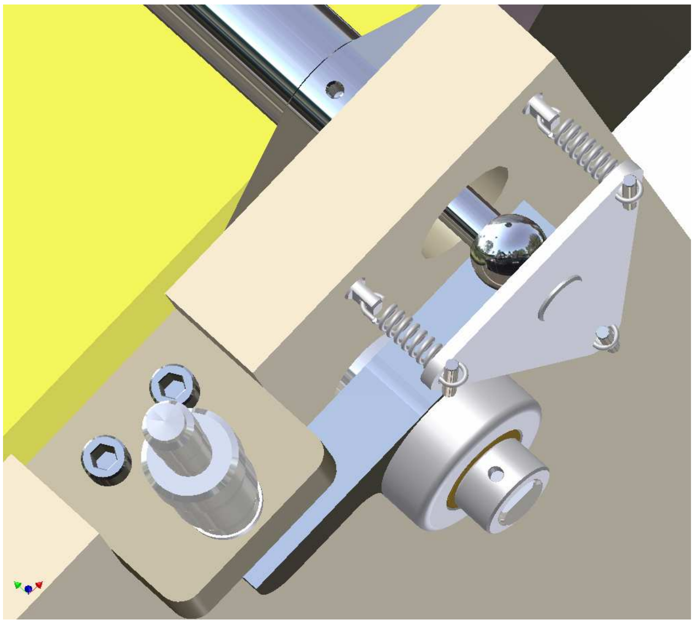

Figure 15: Échelle pitch and yaw mechanism.

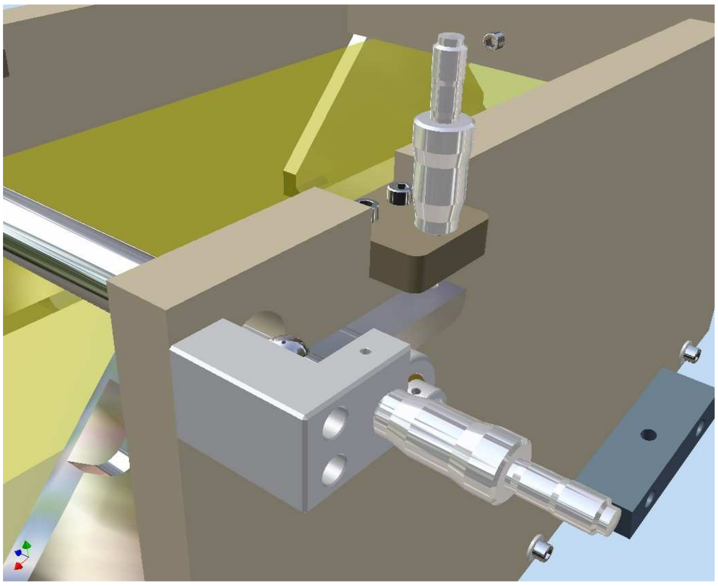

Figure 16: Échelle yaw micrometer (tilt micrometer at rear)

3.5 Dichroic and red and blue fold mirrors

The size and weight of these components will make their mounting and adjustment a relatively simple proposition (see Figures 17 and 18). Movement in X and Y are required as well as rotation about the Z axis. These adjustments will be required at installation and should not require further operator adjustment except in the event of an earthquake or a major overhaul of the instrument. The slow shutter arrangements for the fold mirrors (which is shown retracted in Figure 18) are described in Section 3.8 and their control in 3250AE0029.

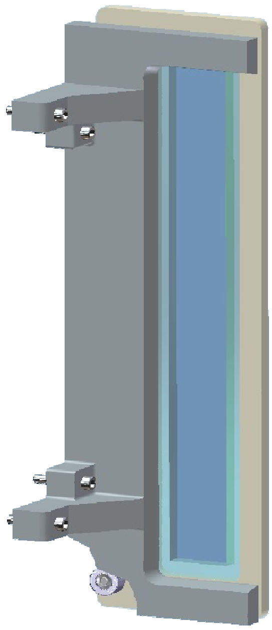

Figure 17: Dichrioc mounting (pivot shown cutaway)

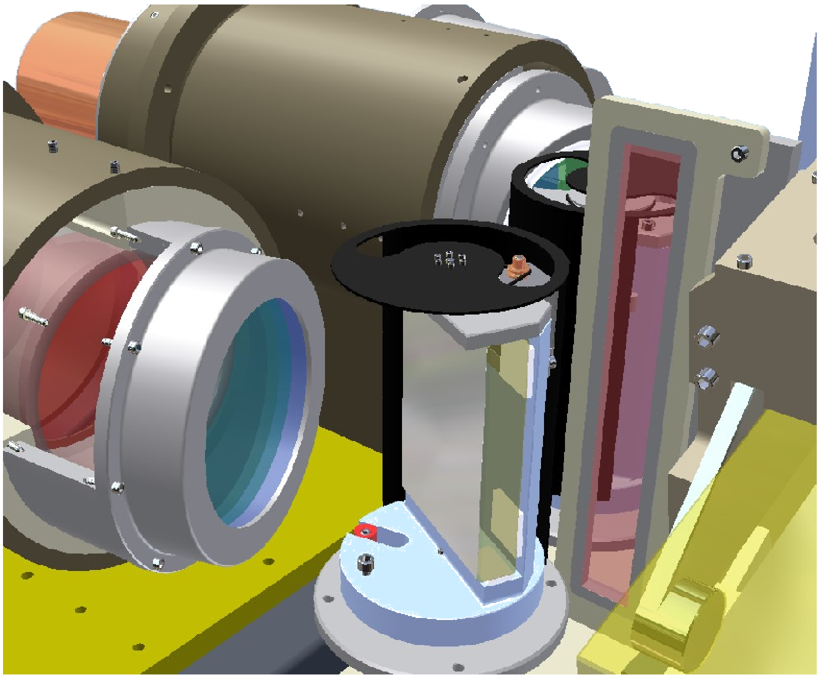

Figure 18: Dichroic, red output fold mirror (with slow shutter retracted) and red camera assembly.

3.6 Red and blue pupil mirrors

Figure 19 shows the red pupil mirror and its support structure on the optical bench weldment. The alignment required in the assembly and initial testing phase is as described for the collimator mirror. The pupil mirrors are also used for spectrograph focus and this arrangement is described in Section 3.8 and their control in 3250AE0029.

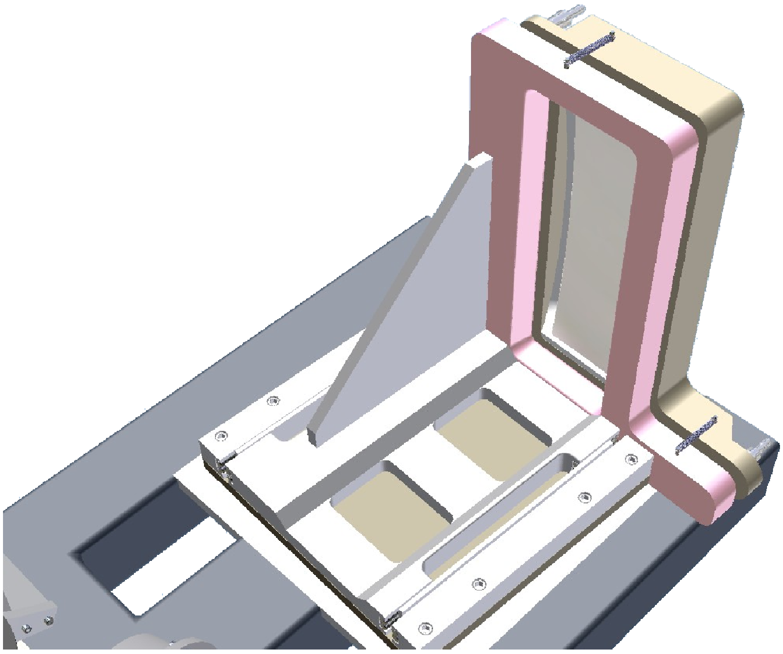

Figure 19: Red pupil mirror assembly.

3.7 Red and blue camera lens assemblies, including VPH gratings

These cameras are a complex arrangement of groups of lenses and have tight tolerances on the lens centring and spacing. The tolerances are presented in 3210AA0007. The barrel arrangement and sub-assemblies used in these cameras have been developed such that they will meet these tight tolerances.

Figures 20 and 21 (the latter from 3220AD0005-000F2) show cutaway and cross-sectional detail of the lens assemblies, including the mounting of the VPH grating and lens assembly at the front of each and the mounting position for the CCD detector system at the output end.

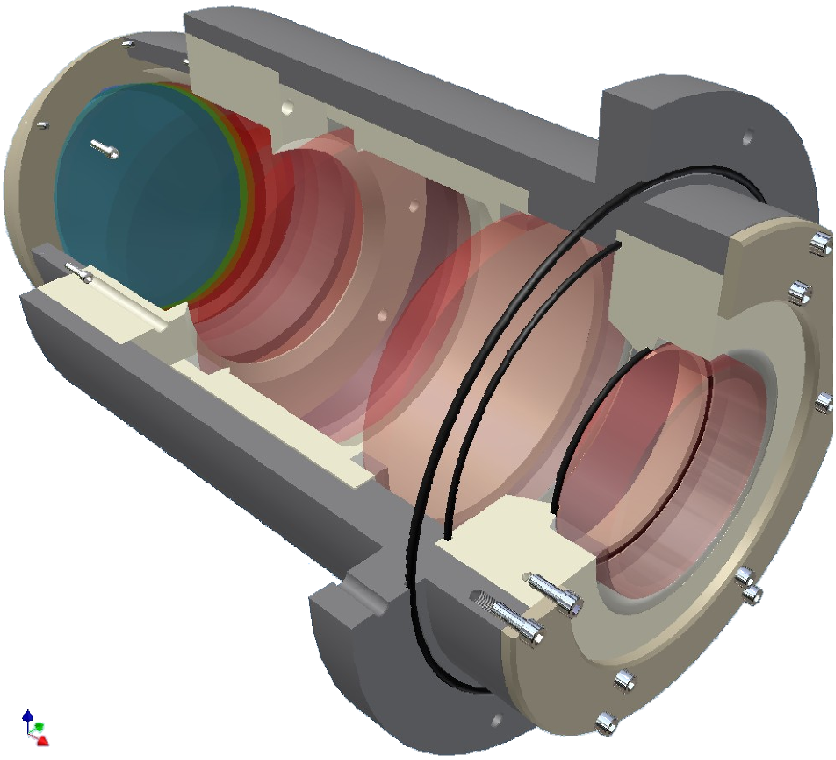

Figure 20: Red camera lens assembly (cutaway). VPH grating is mounted to front (far end) of lens assembly. CCD detector is mounted at the near end of the lens assembly.

Figure 21 shows a cross section through the blue camera. The use and position of RTV732 (or alternatively Silgard 184 and 186) elastomer is indicated. The position and mount of the VPH grating is also shown in this figure.

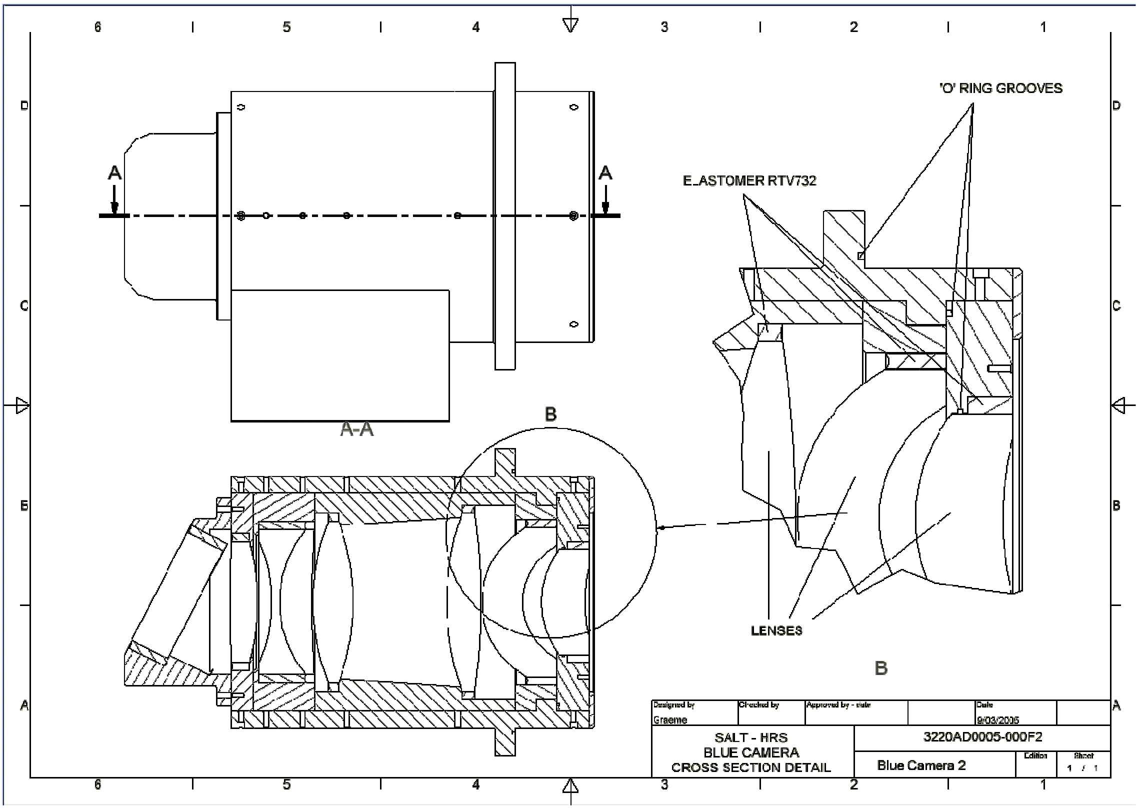

Figure 21: Cross-sectional diagram of the blue camera (320AD0005-000F2).

3.8 Description of user operated moving parts

The user-operated moving parts are the input fold (also called the flip) mirror for direct fibre input or for image slicer operation, the slit-viewing mechanism (within the input pocket and described in 3230AE0030), the focus mechanism using small movements of the pupil mirrors and the two fast (one of these is described in 3230AE0030) and two slow shutters. Their control is described and detailed in 3250AE0029.

3.8.1 Input fold mirror and internal fast shutter

The input fold mirror (see Figure 22) is externally controllable to enable user-operated control of the different resolving power modes. The lowest resolving power uses direct fibre injection through a feed-through in the tank wall and they are fixed to the échelle grating mount, as is the internal fast shutter (see Figure 23). There is *xyz* movement of this mounting for initial alignment purposes.

3.8.2 Focus mechanism using pupil mirrors

The respective spectral images will be focused using a ThorLabs motorised and encoded micrometer (Figure 24) adjusting the position of their respective pupil mirror (see Figure 25 and also Figure 19 in Section 3.6). The micrometers are vacuum rated to 10^{-6} torr.

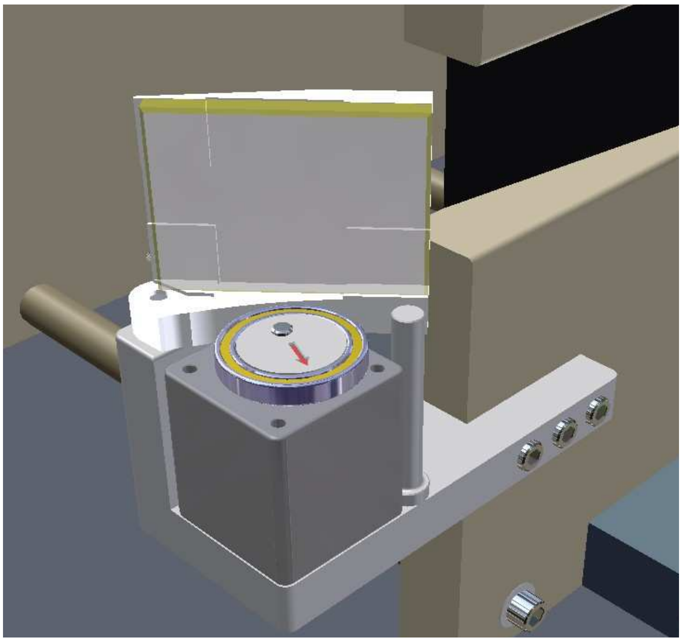

Figure 22: Input fold mirror and mount (see also Figure 6).

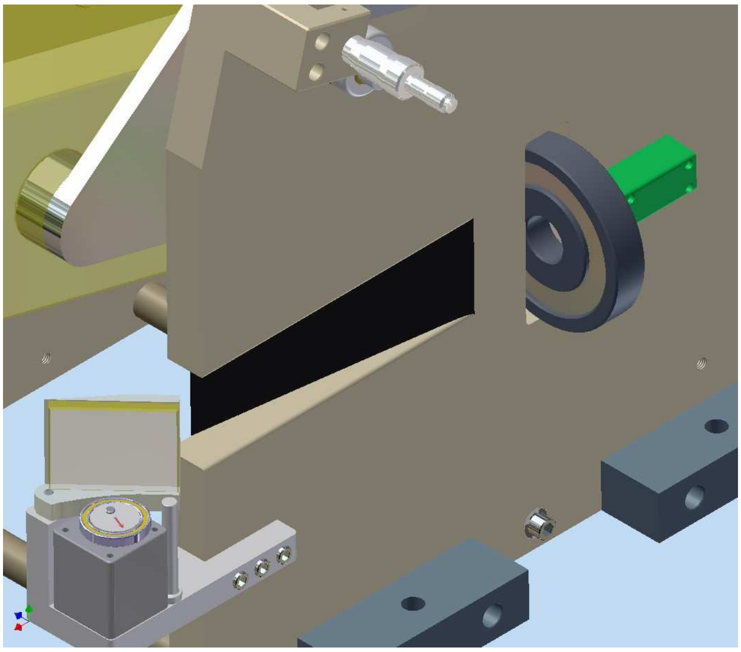

Figure 23: Fast shutter on THE direct input fibre input.

Figure 24: Motorised encoded micrometer for focusing of cameras.

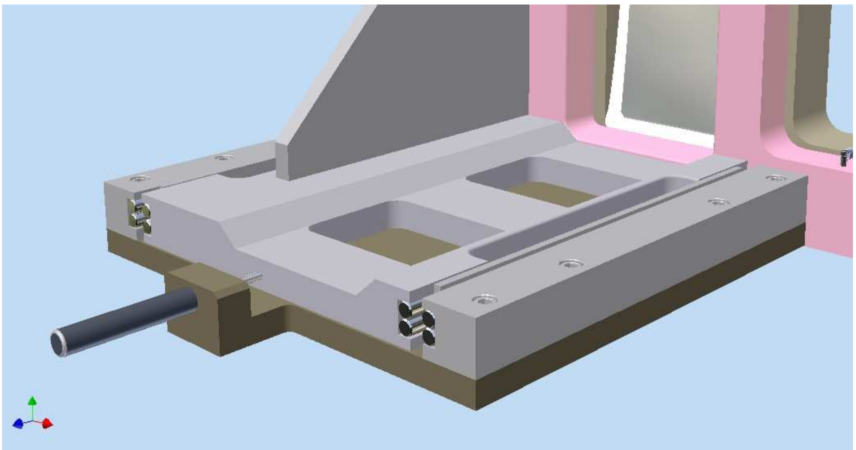

Figure 25: Focussing micrometer for pupil mirror shown at left front.

3.8.3 Slow shutters

The slow shutters are used to allow the operator to have independent control of the exposure time for the red and blue cameras. They are controlled through the SALT HRS PC and this control process is described in 3250AE0029.

Figure 25 shows the shutter in its closed position whereas Figures 6 and 18 showed the slow shutter open.

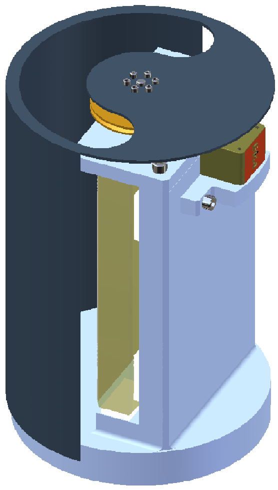

Figure 25: Slow speed shutter (in closed position) and fold mirror. The blue and red paths are identical.

3.9 Environment

It is essential for the proper operation of this instrument that it be enclosed in an insulated and temperature controlled room. A thermally insulated enclosure, with appropriate clean and light tight facilities, will ensure the integrity of the enclosure. To allow for the use of a floor crane, the enclosure will be assembled around the spectrograph after installation. It will be able to be removed to allow future extensive maintenance, but SALT astronomer maintenance will be available through a door in the thermal enclosure.

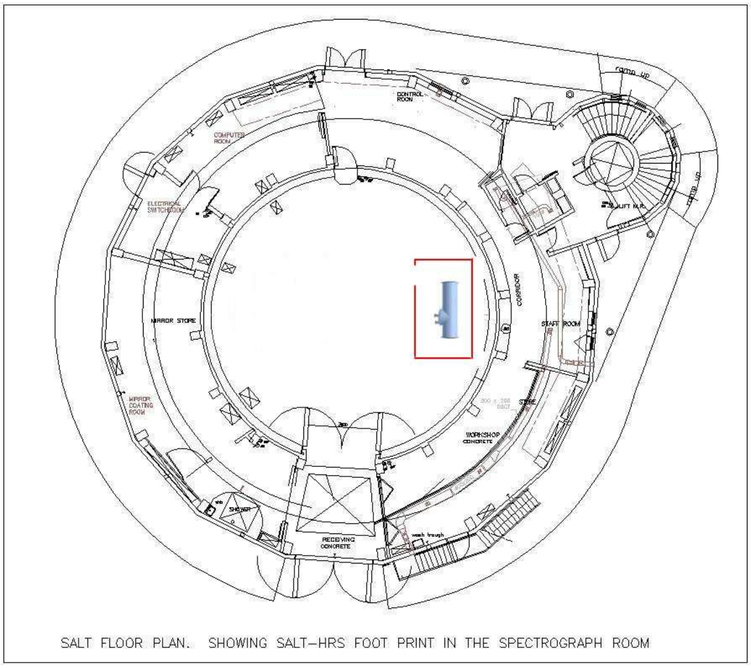

Figure 26: Footprint of the spectrograph in the Spectrograph Room at SALT.

3.10 Handling

A portable, manually operated fork-lift will be provided to lift and position the heavier components during installation and major upgrades. The four access 'lids' (see Figure 1) could also be lifted off by this unit, although for normal access they are hinged directly off the tank.

4 Risks

4.1 The optical components will be handled with a small floor crane and cradles to facilitate their positioning.

5 Safety

5.1 The greatest identified personal risk is that of crushing, both bodily and of appendages. Serious harm can be avoided with the proper use of the handling equipment provided.

5.2 Risk of minor injury can be reduced by common sense and reading any posted hazard warning on the areas of concern.

6 TBCs and TBDs

TBC1: Thickness of elastomer in collimator mirror (3.3).

TBD 1: Slit plate and telecentric lens mounting details.
TBD 2: Direct fibre and fast shutter mounting details.
TBD 3: CCD flat field lamp position and mounting details.